

Process for the Production of Anhydrosugar Alcohols

This application claims priority to provisional application serial number 60/244962, filed on November 01, 2000.

Field of the Invention

The present invention relates to the production of anhydrosugar alcohols. More particularly, the present invention relates to a process for the production of anhydrosugar alcohols from sugar alcohols that does not require the use of organic solvents.

Background

The chemical formation of closed-ring organic molecules has posed many issues for structural organic chemists. This has been particularly true with regard to synthetic reactions involving sugars and polyols, the acid dehydration of which leads to internal anhydro compounds (mono- and dianhydro products). Fleche and Huchette, *Staerke*, 38 (1985) 26-30.

The earliest work in this area was done on 1,4:3,6 – dianhydro-D-mannitol by Fauconnier in 1884. Only sporadic work followed until the 1940's and 1950's, when intensive work was done on all possible isomers of 1,4:3,6 – dianhydro-hexitols. Stoss and Hemmer, *Adv. Carbohydrate Chem. and Biochem.* (1991) 93-173. Since then a large body of chemical literature has developed in this area.

The 1,5:3,6 – dianhydrohexitols belong to the so-called “biomass-derived substances”, obtainable from natural products. Therefore, these compounds are classified as “regenerable resources.” Furthermore, 1,4:3,6 – dianhydrohexitols,

such as isosorbide, can be used as starting materials and intermediates in various organic synthetic reaction schemes. For example, isosorbide is useful in the formation of numerous pharmaceutical compounds, in food production, cosmetic production, plastic and polymer production, and in other industrial uses such as in the production of polyurethane, polycarbonate, polyesters, and polyamides. Stoss and Hemmer, 1991.

Of the known isohexides, isosorbide is considered to be that of the highest importance. Stoss and Hemmer (1991) describe the putative steps leading from D-glucitol (also referred to in the art as sorbitol) to isosorbide. Acidic media are generally used for dehydrating the sugar alcohol substrate. Especially to enhance the yield and to avoid side reactions, certain modifications of the reaction conditions have been employed over the years, with various impacts on yield of isosorbide product. Stoss and Hemmer, 1991.

Several processes for the production of anhydrosugar alcohols (including isohexides such as isosorbide) are known. See, for example, PCT application number PCT/US99/00537 (WO 00/14081), collecting methods and disclosing a continuous production method with recycling of organic solvent. Most methods involve the use of concentrated acids and organic solvents. Goodwin et al. (*Carbohydrate Res.* 79 (1980), 133-141) have disclosed a method involving the use of acidic-cation-exchange resin in place of concentrated, corrosive acids, but with low yield of isosorbide product. An alternative, supersaturation-based method is disclosed in U.S. Patent No. 4,564,692 (Feldmann et al., Jan. 14, 1986). However, a need continues in the art for a process for production of very pure

isosorbide, at reasonable yields, and preferably without the use of potentially hazardous organic solvents.

Summary of the Invention

The present invention relates to a process for the preparation of anhydrosugar alcohols from sugar alcohol starting materials. The process results in very pure products, with relatively high yields, without the use of organic solvents.

In general, the process involves the heating of the appropriate sugar alcohol starting material, with stirring, until molten; dehydrating the molten starting material in the presence of an appropriate catalyst (e.g., a soluble acid or an acidic ion exchange resin), with stirring, and under vacuum at elevated temperature; purifying the anhydrosugar alcohol, for example by distillation, and then by melt crystallization and/or redistillation; and isolating the final, purified product (for example, by centrifugation or, alternatively, by filtration).

Detailed Description

The present invention provides a solvent-free process for the production of very pure anhydrosugar alcohols. The process of the invention generally includes the steps of melting a sugar alcohol starting material, maintaining the elevated temperature and adding an appropriate catalyst and applying a vacuum, with stirring, for a length of time (which will depend upon the reaction conditions) sufficient to remove all water. The resultant anhydrosugar alcohol mixture is then subjected to a purification and separation process, and an anhydrosugar alcohol product of high purity is produced.

Typical sugar alcohols, particularly pentites and hexites, are suitable for use as starting materials in the process of the invention. The starting materials can include sugar alcohols, monoanhydrosugar alcohols, or a mixture of such alcohols. Generally the preferred starting materials include arabinitol, ribitol, D-glucitol (also referred to in the art as D-sorbitol or sorbitol, and referred to herein as sorbitol), D-mannitol (or mannitol), galactitol (dulcitol), iditol, and the like. Sorbitol is a particularly preferred starting material because it is readily available, and because pure isosorbide is very useful in a number of chemical and pharmaceutical applications.

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In the first step of the process of the present invention, the selected starting material is melted. If, by way of example, sorbitol is the starting material, it is heated to at least about 100°C, or at least to its melting point. For anhydrosugar alcohols generally this temperature is from about 100°C to about 191°. For sorbitol powder, to provide a specific example, the preferred melting temperature is from about 98°C to about 105°C; an even more preferred melting temperature is from about 98°C to about 100°C. Once molten, the sorbitol is subjected to stirring.

A catalyst that will facilitate the dehydration of the sugar alcohol is then added to the molten starting material. Typically the catalysts used to facilitate the dehydration of sugar alcohols are acid catalysts. The classes of acid catalysts useful in the practice of the present invention are soluble acids, acidic ion resins, and inorganic ion exchange materials. Therefore, acids such as sulfuric acid, phosphoric acid, p-toluenesulfonic acid, p-methanesulfonic acid, and the like, are

preferred for use in the present invention. Alternatively, for example, Zeolite powders such as CBV 3024 or CBV 5534G (available from Zeolist International), or T-2665 or T-4480 (available from United Catalysis, Inc.), or the like, can be used in the practice of the invention. More preferred are acidic ion resins such as AG50W-X12 from BioRad Laboratories, Amberlyst 15 or 35 from Rohm & Hass, and RCP21H from Mitsubishi Chemical Corp., as well as Dowex 50Wx4 (Dow Chemical Co.). Amberlyst 35 is a particularly preferred resin in the practice of the present invention, specifically for the production of isosorbide from sorbitol.

The amount of catalyst used will vary depending upon the reaction conditions and starting material, as those of skill in the art will appreciate, but will generally be on the order of from about 0.01 equivalents to about 0.15 equivalents by weight. The currently preferred amount of catalyst is 0.1 equivalents by weight.

It is possible to perform one or two dehydrations of the starting sugar alcohol during the reaction, producing a mono- or dianhydrosugar alcohol. The reaction may also be controlled so as to produce a combination of mono- and dianhydrosugar alcohols by adjusting either the reaction conditions or the starting materials, which as those of skill in the art will appreciate, could contain both sugar alcohols and monoanhydrosugar alcohols.

The dehydration in the presence of the catalyst is carried out under a vacuum, at elevated temperatures, and with stirring of the reaction mixture. The vacuum can range over a pressure of from about .05 Torr to about 40 Torr, with preferred pressures of from about 1 Torr to about 10 Torr. As a specific example,

the currently preferred pressure for the dehydration step in the process of the present invention in which isosorbide is made from sorbitol is from about 1 Torr to about 10 Torr. In the production of isosorbide from sorbitol, the dehydration is carried out for approximately 2 hrs, with constant stirring, at a temperature of about 120°C. The water is pulled off of the melted sorbitol/catalyst mixture under a vacuum of from about 1 Torr to about 10 Torr.

It will of course be appreciated by those of skill in the art that, in a process such as that of the present invention, which involves application of both elevated temperatures and vacuum, the specific parameters of the process, including the time it takes to carry certain steps to completion, will vary depending upon the temperatures and pressures used. As one of skill in the art would anticipate, for example, the inventors have determined that higher vacuum levels for the distillation step gave the expected lower distillation temperature. An additional variable is the selected starting material, which will have a particular melting and/or distillation point (the latter, of course, being dependent upon the vacuum). This is equally true for the purification process described below. However, given the disclosure presented herein, it is within the level of skill in the art to optimize the process parameters of the invention for a particular application. This can be done with only a few preliminary experiments, and without undue experimentation, in light of the instant disclosure.

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Following the dehydration procedure, the resultant mixture is purified. In a preferred embodiment, vacuum distillation is used, although alternatives such as filtration, or the addition of activated charcoal with subsequent crystallization, are

available. As noted above, the parameters for vacuum distillation will vary depending upon the material to be purified, and the temperature and pressure, as will be appreciated by those of ordinary skill in the art. The pot temperature will of course depend upon the temperature at which the material to be purified distills (the distillation point), which again will depend on the vacuum applied in the system. For example, in the case of isosorbide, a range of vapor temperatures of from about 155°C to about 170°C is preferred; more preferred is from about 160°C to about 170°C; even more preferred is from about 165°C to about 170°C. The vacuum pressure can be from about .05 Torr to about 40 Torr; preferably from about 1 Torr to about 10 Torr. For example, and specifically with regard to vacuum distillation of isosorbide, a vacuum pressure of from about 1 Torr to about 10 Torr, a pot temperature of about 180°C and a vapor temperature of from about 160°C to about 170°C are currently most preferred.

In order to further purify and isolate the anhydrosugar alcohol, the anhydrosugar alcohol distillate is subjected to melt crystallization. The recovered distillate product is heated to its melting point (e.g., for isosorbide, to approximately 65°C) until molten, and then cooled over time until the crystallization point is reached, but not so much that the material solidifies. In fact, a slurry-like consistency is preferred, so that the material can be centrifuged. The centrifugation is performed at a relatively high speed for a relatively short period of time, again in order to avoid solidification of the material, and also to avoid having the desired purified anhydrosugar alcohol end product be drawn off with the remaining impurities. The resultant anhydrosugar alcohol product should

be at least 98% pure, and in most cases will be >99% pure (depending upon the solidity of the "slurry").

The present invention is described in further detail in the following non-limiting examples.

Example 1

This Example describes the production of very high purity isosorbide from sorbitol using a particularly preferred embodiment of the process of the present invention.

Sorbitol powder (180.6 grams, 0.99 mol) was placed in a 3-neck round bottom flask equipped with an agitator, temperature probe, and vacuum line. The sorbitol was heated to approximately 100°C until molten. An acidic ion exchange resin, Amberlyst 35 (Rhom & Haas) (19.8grams) was added and vacuum was applied at from about 1 Torr to about 10 Torr. The temperature was increased to from about 120°C to about 130°C. These temperature and vacuum parameters were maintained for approximately 2 hours, with constant stirring. The resultant mixture was then vacuum distilled at from about 1 Torr to about 10 Torr, pot temperature of 180°C, vapor temperature of 170°C. The distillate was collected and subjected to melt crystallization by heating to approximately 65°C until molten, then cooling, over about 30 minutes to about 45 minutes to approximately 35°C, at which temperature a slurry-like solution was formed. This solution was then quickly centrifuged (in order to avoid solidification), and the resultant isosorbide product had a purity of 99.3%, with an overall yield of 48%.

Example 2

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The same apparatus and the same operational conditions-except those specified below-as in Example 1 were used. Upon heating sorbitol to $\sim 100^{\circ}\text{C}$ to a molten state, an acidic ion exchange resin, Amberlyst 15 (Rohm and Haas, 24.2g), was added and vacuumed applied (5-7 Torr). Heating was increased to 135°C and the reaction allowed to stir continuously for $\sim 2\text{h}$. The resulting mixture contained 64.5% isosorbide and was then purified by the procedure described in Example 1.

Example 3

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The same apparatus and the same operational conditions-except those specified below-as in Example 1 were used. Upon heating sorbitol to $\sim 100^{\circ}\text{C}$ to a molten state, an acidic ion exchange resin, Dowex 50WX4, (18.1g), was added and vacuumed applied (7-9 Torr). Heating was increased to 135°C and the reaction allowed to stir continuously for $\sim 2\text{h}$. The reaction mixture contained 64.1% isosorbide. Purification was then performed.

Example 4

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The same apparatus and the same operational conditions-except those specified below-as in Example 1 were used. Upon heating sorbitol to $\sim 100^{\circ}\text{C}$ to a molten state, the acidic ion exchange resin, Amberlyst 35 (Rohm and Haas, 11.7g), was added and vacuumed applied (9-12 Torr). Heating was increased to 135°C and the reaction allowed to stir continuously for $\sim 2\text{h}$. The resulting

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mixture contained 18.6% sorbitan and 73.4% isosorbide. The mixture was then purified using the above described procedure.

Example 5

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The same apparatus and the same operational conditions-except those specified below-as in Example 1 were used. Upon heating sorbitol to $\sim 100^{\circ}\text{C}$ to a molten state, the acidic ion exchange resin, RCP21H (Mitsubishi Chemical Corporation, 12.9g), was added and vacuumed applied (7-9 Torr). Heating was increased to 135°C and the reaction allowed to stir continuously under vacuum for $\sim 5\text{h}$. The resulting mixture contained 68.9% isosorbide. The mixture was then purified using the above described procedure.

Example 6

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The same apparatus and operational conditions-except those specified below-as in Example 1 were used. Sorbitol (221.4 g, 0.99 mol) was heated to $\sim 100^{\circ}\text{C}$ to a molten state. At this time, a sulfated zirconia pellet (#416/03 Japan Energy Corporation, 57.7g), was added and vacuumed applied (5-7 Torr). Heating was increased to 150°C and the reaction allowed to stir continuously for $\sim 7\text{h}$. The resulting mixture contained 2.2% sorbitol, 56.0% sorbitan and 22.9% isosorbide.

Having now fully described the present invention in some detail by way of illustration and example for purposes of clarity of understanding, it will be obvious to one of ordinary skill in the art that the invention can be performed by modifying or changing the invention with a wide and equivalent range of conditions, formulations and other parameters thereof. Furthermore, it will be obvious to the skilled practitioner that such modifications or changes are intended to be encompassed within the scope of the appended claims.

All publications, patents and patent applications mentioned in this specification are indicative of the level of skill of those skilled in the art to which this invention pertains, and are herein incorporated by reference to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated by reference.